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Composite Replacement Panel Strain Survey (CRPSS) – Test Plan

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ABSTRACT

The Defence Science and Technology Organisation, in collaboration with the Cooperative Research Centre for Advanced Composite Materials, is developing the capability to replace metallic aircraft panels with those manufactured from advanced fibre composites. This is known as the Composite Replacement Panel Technology (CRPT). One step toward airworthiness certification of the CRPT is a validated capability to predict strain within a composite replacement panel (CRP) and the aircraft sub-structure. The strain data required for this validation shall be obtained in the Composite Replacement Panel Strain Survey (CRPSS). In the CRPSS, the strains within a demonstrator CRP installed on a F-111C aircraft shall be measured during a Cold Proof Load Test to be conducted at RAAF Base Amberley in June 2004. This report describes the procedures to be used for the CRPSS.

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Composite Replacement Panel Strain Survey (CRPSS) – Test Plan

Executive Summary

The Defence Science and Technology Organisation (DSTO), in collaboration with the Cooperative Research Centre for Advanced Composite Structures (CRC-ACS), is developing the Composite Replacement Panel Technology (CRPT). The aim of this technology is to provide the Australian Defence Force with an alternative for the through-life-support of structural aircraft panels. Many existing bonded metallic panels are expensive to support because the materials, pre-bonding surface treatments and thin skins used in their construction make them susceptible to damage from corrosion, fatigue, disbonding and impact.

The CRPT approach will be to replace metallic panels with those constructed from advanced composite material. Composite Replacement Panels (CRPs) would be significantly more durable than the existing aluminium panels because composites are resistant to corrosion and fatigue, and the panel configuration would be designed to enhance impact resistance. Manufacturing costs would be competitive because CRPs would be manufactured from composite materials that cure at low temperature in an oven, rather than the traditional autoclave processing. Finally, certification costs would be low because the CRPT itself, rather than each panel design, would be certified.

An important step toward airworthiness certification of the CRPT is a validated capability to predict strain within CRPs and the aircraft sub-structure. The aim of the Composite Replacement Panel Strain Survey (CRPSS) is to provide the strain data for this validation.

A low cost option (relative to flight-testing or full-scale testing with representative loading) is to conduct the CRPSS on a F-111 aircraft undergoing a Cold Proof Load Test (CPLT). In the CPLT, the entire aircraft is cooled to -40°C and critical airframe components subjected to design limit load. The well-defined load and temperature in the CPLT will ease greatly the interpretation of the strain data.

The CRPSS shall consist of an instrumented CRP installed on an instrumented F-111 undergoing a CPLT. It shall be conducted at Royal Australian Air Force (RAAF) Base Amberley in June 2004. The CRPSS test procedure is summarised below and detailed in this report:

1. Remove existing Panels 3208 (Part Number 12B-3913) and 3108 (same position as Panel 3208 but on opposite side of aircraft) from the aircraft.
2. Install strain gauges to the aircraft sub-structure beneath Panels 3208 and 3108.
3. Install strain gauges onto Panel I (Part Number CRC-ACS-511b-PN-001, a demonstrator CRP for F-111C Panel 3208).
4. Install Panels I and 3108 onto the aircraft.
5. Install strain gauges onto Panel 3108 and the local aircraft skin.
6. Connect all strain gauges to a data acquisition system.
7. Acquire data prior to, and during, the CPLT.
8. Remove Panels I and 3108 from the aircraft.
9. Remove strain gauges and restore surfaces on the sub-structure and Panel 3108.
10. Re-install the original metallic Panels 3208 and 3108 onto the aircraft.

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1. Scope

1.1 Objective

An important step toward airworthiness certification of the Composite Replacement Panel Technology (CRPT) is a validated capability to predict the strains in Composite Replacement Panels (CRPs) and the aircraft sub-structure under the combined action of mechanical and thermal load. The aim of the Composite Replacement Panel Strain Survey (CRPSS) is to provide the strain data for this validation. Subsequent analysis shall be performed to correlate the strains recorded during the CRPSS with the predictions made by finite element analysis, thereby validating the predictive capability.

This document describes the procedures to be used for conduct of the CRPSS.

1.2 Background

The Australian Defence Force (ADF) operates most aircraft types well beyond their original design lives. This has been a very cost effective way for a small country such as Australia to maintain an effective defence capability. However this approach has brought several problems. As operational lives have increased, the provision of support services from the Original Equipment Manufacturer (OEM) has become increasingly difficult and, in some areas, ceased to exist. Structural panels on most aircraft have a finite life. The metallic materials suffer from corrosion damage and fatigue cracking; thin walled construction has been susceptible to impact; and disbonding occurred where inappropriate pre-bonding surface treatments were applied. Through-life-support costs for such panels have become very high, particularly where repair limits have been reached and the panel must be replaced. Typically the OEM has had a captive market for these components.

DSTO, in collaboration with the Cooperative Research Centre for Advanced Composite Structures (CRC-ACS), has developed the CRPT. The aim of this technology has been to provide the ADF with an alternative for the through-life-support of aircraft containing structural panels. CRPs are expected to enable ageing aircraft to continue to operate when the original parts are either unavailable or excessively expensive to support or purchase.

The CRPT approach has been to replace the metallic panels with panels constructed from advanced composite material. These CRPs would be significantly more durable than the existing aluminium panels because the composite materials are resistant to corrosion and fatigue cracking, and the panel configuration would be designed to enhance impact resistance. Manufacturing costs would be competitive because low temperature composite materials would be used. These composites may be cured in an oven under vacuum pressure only, they would not require the expensive tooling and autoclave curing required for traditional aerospace composites. Finally, certification costs would be low because the CRPT itself would be certified. For any specific panel only those aspects that were different from the approved set of design solutions would need to be tested.

An important step toward airworthiness certification of the CRPT is validation of the capability to predict strain within CRPs and the aircraft sub-structure under representative conditions.

A demonstrator CRP has been produced as a replacement for F-111C Panel 3208. Although its formal designation is Part Number CRC-ACS-PN-511b-01, it shall be identified as Panel I throughout this report for brevity and to distinguish it from the original metallic panel, Part Number 12B-3913, identified as Panel 3208 throughout this report.

The traditional methods of obtaining the strain data necessary to validate a predictive capability have been to conduct flight tests or perform full-scale tests using representative loading and non-ambient temperature. Both of these options were prohibitively expensive for the CRPT. Fortunately, as part of the safety-by-inspection program, F-111 aircraft are subjected to the Cold Proof Load Test (CPLT). The CPLT is a proof test designed to load critical D6ac steel components of the F-111 airframe to their Design Limit Load (DLL). In D6ac steel the critical crack size required to cause catastrophic failure falls with temperature. The CPLT is conducted at -40 °C to prove that, provided the aircraft survives the CPLT, any cracks within the D6ac components must be sufficiently small that they will not grow to a critical length prior to the next CPLT.

The well-defined load and temperature in the CPLT, and access to the F-111 Internal Loads Finite Element Model, will ease greatly the interpretation of strain data from the CRPSS. The CRPSS shall therefore consist of an instrumented CRP (Panel I) installed on an instrumented F-111 undergoing a CPLT.

A numerical analysis of the CRPSS was conducted and has concluded that the structural aspects of the CRPSS have been addressed satisfactorily [1]. This analysis has been accepted [2] by an Authorised Engineering Organisation (AEO). In preparation for the CRPSS, the required Australian Defence Force documentation has been prepared [3 to 5].

1.3 Test Overview

The CRPSS shall consist of the following activities:

1. removal of the existing Panels 3208 and 3108 (same position as Panel 3208 but on opposite side of aircraft) from the F-111C aircraft,
2. installation of strain gauges to the sub-structure beneath Panels 3208 and 3108,
3. installation of strain gauges to Panel I,
4. installation of Panels I and 3108 to the aircraft,
5. installation of strain gauges to Panel 3108 and the local aircraft skin,
6. connection of all strain gauges to the data acquisition system,
7. data acquisition during CPLT,
8. removal of Panels I and 3108,
9. removal of strain gauges on the skin, sub-structure and Panel 3108 then restoration of all surfaces,
10. installation of the original metallic panels (Panel 3208 and 3108).

2. Personnel, Tools and Equipment

The functions required to conduct the CRPSS have been coded and are shown in Table 1.

Table 1: Functions and organisations responsible for the CRPSS

Code	Function	Organisation
MNT	F-111 Maintenance	Boeing Aerospace Limited (BAL)/SRSPO
CMP	Trim and drill of Panel I	BAL under supervision of CRC-ACS
SGA	Strain gauge application	Fortburn Pty Ltd
DAS	Data acquisition installation and operation	PraxSys under sub-contract from Fortburn Pty Ltd
CPL	CPLT operation	BAL
PMG	Project Management	DSTO/BAL/SRSPO/ AeroStructures
TOV	Test Overview	DSTO/BAL/SRSPO/ AeroStructures

These codes are used in Sections 9 to 13 to identify the type of, and organisation(s) responsible for, work in the CRPSS. The supply of appropriate tools and equipment is the responsibility of the organisation conducting each function.

3. Test Management

The following people shall be responsible for the management of the CRPSS.

1. Mr A. Harper
Senior Engineer
AeroStructures
Level 14, 222 Kingsway
South Melbourne VICTORIA 3205
2. Dr P. Callus
Senior Research Scientist
Air Vehicles Division
Defence Science and Technology Organisation
506 Lorimer St
Fishermans Bend VICTORIA 3207
3. FLTLT M. Sciberras
DESACC1
Strike Reconnaissance Systems Program Office
RAAF Base Amberley
QUEENSLAND 4306
4. Mr A. Kendal
Project Manager
Boeing Aerospace Limited
Boeing Aerospace Support Centre
PO Box 54
Amberley
QUEENSLAND 4306

4. Schedule

The schedule of work to be conducted for the CRPSS shall be proposed by BASC. Wherever possible DSTO shall comply with the timetable proposed by BASC. Any clashes shall be resolved by negotiation. The overall aim is not to interfere with the BASC schedule for completion of any CPLT.

5. Test Fixture

The test fixture for CPLT loading is custom built for the F-111 aircraft and located in the CPLT facility at RAAF Base Amberley. Full details of the fixture and its application are provided in reference [6].

6. Test Loading

The CRPSS shall consist of a single Cold Proof Load Test (CPLT) cycle applied to a F-111 aircraft on which Panel I shall be installed. The CPLT shall consist of the following four load cases:

CPLT I	-2.40 g	+56° wing sweep
CPLT II	+7.33 g	+56° wing sweep
CPLT III	-3.00 g	+26° wing sweep
CPLT IV	+7.33 g	+26° wing sweep

These load cases are hard coded into the CPLT control system. Details of the individual actuator loads and the locations of each actuator are provided in reference [6].

6.1 Test Environment

The CPLT shall be conducted under the prescribed temperature (-40 °C) and humidity conditions (ambient humidity at test temperature) of the CPLT.

7. Data Acquisition

An external contractor, Fortburn Pty Ltd, shall perform the strain gauging. Fortburn Pty Ltd shall employ a sub-contractor, PraxSys Pty Ltd, to provide and operate the data acquisition system. The data acquisition system is described in reference [7].

Both the strain gauge contractor and the data acquisition sub-contractor have extensive experience in applying strain gauge sensors and recording strain data on aerospace components. They were both used for the F-111C Fuselage Strain Survey, where over 700

strain gauges were applied to an F-111 aircraft that was subsequently subjected to a Cold Proof Load Test.

Fortburn Pty Ltd is a member of the Defence Industrial Security Program and all strain gauging technicians are defence cleared personnel. All quality procedures and manuals are in accordance with AS/NZS 9002.

8. Strain Gauge Locations

A summary of strain gauge details for the CRPSS is given in Table 2. Full details are given in Appendix A. The columns in Table 2 refer to the;

- a. strain gauge number
- b. drawing number (drawings shown in Appendix B), showing strain gauge location
- c. section of this report where the gauge installation is specified, and
- d. references the documents that specify paint removal and strain gauge installation.

The nomenclature for the strain gauge number is:

CRPSS_nnnTSNN

where:

CRPSS	reference to the Composite Replacement Panel Strain Survey
nnn	fuselage station to the closest whole inch
T	type of strain gauge; A for axial or R for 0/45/90 rosette
S	side of the aircraft; L for left (port) or R for right (starboard)
NN	sequential number, starting from 01, of gauges with the same nnn, T and S

9. Test Article Preparation

The aircraft shall undergo usual servicing in preparation for its scheduled CPLT. At a time designated by BASC, the aircraft shall be fitted with strain gauges and Panel I, in accordance with (IAW) Sections 9.1 to 9.5.

9.1 Aircraft Selection

1. PMG The timing of the CRPSS shall be selected by BASC and SRSP0 in consultation with DSTO. It shall be the next F-111C undergoing CPLT following completion of the documentation and approval of a BASC Deviation/Waiver. It is expected to be conducted in June 2004 on tail number A8-143.

Table 2. Strain gauge details for the CRPSS

Gauge number	Location	Part number	AeroStructures Drawing Number ¹	Section where installation specified	Reference for	
					Paint removal	Gauge application
CRPSS_496AL01	FS 496 Former	12B-2908	919	9.3	8	9
CRPSS_496AR01						
CRPSS_496AL02		12B-2909				
CRPSS_496AR02						
CRPSS_505RL01	Skin	12B-3945	922	9.5	8	9
CRPSS_505RR01						
CRPSS_508AL01	Lower Beam	12B-4912	921	9.3	8	9
CRPSS_508AR01						
CRPSS_510AL01	Longeron	12B-1904	923		10	11
CRPSS_510AR01						
CRPSS_514RL01	Skin	12B-3913	924	9.5	10	11
CRPSS_531AL01	FS 531 Former	12B-2922	920	9.3	10	11
CRPSS_531AR01						
CRPSS_508RR01	Skin	Panel I	925	9.4	10	11
CRPSS_508RR02						
CRPSS_509RR01						
CRPSS_522RR01						
CRPSS_522RR02						
CRPSS_522RR03						

Note:

¹ Number is nnn from AeroStructures Drawing Number ED-F111-51-APMnnn

9.2 Removal of Panel 3208 and 3108

- 1. MNT Panel 3208 shall be removed from the Right Hand Side (RHS) and Panel 3108 from the Left Hand Side (LHS) of the selected aircraft IAW BASC standard operating procedures [12].

9.3 Installation of Strain Gauges on Sub-Structure

- 1. SGA The following strain gauges, as defined in Table 2, shall be prepared for installation:
 - a. CRPSS_496AL01
 - b. CRPSS_496AR01
 - c. CRPSS_496AL02
 - d. CRPSS_496AR02
 - e. CRPSS_508AL01
 - f. CRPSS_508AR01
 - g. CRPSS_510AL01
 - h. CRPSS_510AR01
 - i. CRPSS_531AL01
 - j. CRPSS_531AR01

2. SGA For each of these locations the surfaces shall be prepared and strain gauges bonded IAW:
 - a. references [13 to 15],
 - b. the references specified in Table 2,
 - c. the following warnings for working on D6ac steel:
 - do not mark surface with lead pencil
 - D6ac is highly sensitive to corrosion and only approved materials and solvents are to be used. The use of other materials could initiate hydrogen embrittlement of the steel, and
 - d. Steps 3. to 12. of Section 9.3.
3. SGA When cleaning aluminium surfaces IAW reference [10] Step 8, immediately wipe the alcohol dry after use. Do not allow solvent to evaporate before wiping.
4. SGA During surface preparation the surface roughness is to be better than 64 Ra. This is generally achieved using the techniques described in references [9, 11].
5. SGA When aligning the strain gauge IAW references [9, 11] Step 4, mark the aluminium tape surrounding the installation location, not the sub-structure.
6. SGA When soldering lead wires IAW references [9, 11] Step 12, the lead wire shall be 100 mm to provide the flexibility to redirect the wires around fastener heads or any other surrounding structure.
7. SGA When sealing the gauge and exposed metal IAW reference [9, 11] Step 13:
 - a. allow 20 minutes for the M-Coat D to dry, depending on ambient temperature and humidity, before recoating and allowing a further twenty four hours to dry, and
 - b. apply an approximately 2.5 mm thick layer of Cautaulds PR 1750A1/2 sealant over the M-Coat D.
8. SGA The Engineering Data Sheet for each batch of strain gauges shall be retained.
9. SGA The strain gauge installation sheet [16] shall be completed for each strain gauge installed.
10. SGA Two digital photographs shall be taken of each strain gauge after bonding/sealing/soldering is complete. The photographs shall be a far field view of the gauge identifying some structural feature and a close up of the gauge.
11. MNT The following unservicabilities shall be entered into the aircraft EE500:
 - a. Power is not to be applied to the aircraft. Refer to BASC-D/W-000761.
 - b. Aircraft is not to be refuelled. Refer to BASC-D/W-000761.
12. MNT BASC shall conduct a Physical Condition Audit (PCA).

9.4 Preparation and Installation of Panel I and Panel 3108

1. SGA The following strain gauges, as defined in Table 2, shall be prepared for installation:
 - a. CRPSS_508RR01
 - b. CRPSS_508RR02
 - c. CRPSS_509RR01
 - d. CRPSS_522RR01
 - e. CRPSS_522RR02
 - f. CRPSS_522RR03
2. SGA For each of these locations the surfaces shall be prepared and strain gauges bonded IAW:
 - a. references [13 to 15],
 - b. the references specified in Table 2, and
 - c. Steps 4, 5, 6, 7, 8, 9 and 10 of Section 9.3.
3. CMP Panel I shall be trimmed and drilled IAW reference [17].
4. CMP It is possible that the duct shown in Fig. 1 may interfere with the hat stiffeners and prevent Panel I from being fastened to the aircraft. If this occurs then:
 - a. trim the hat stiffeners until they clear the duct (maximum allowable trim depth is 10 mm), and
 - b. reinforce any trimmed stiffeners IAW Appendix C.
5. CMP Panel I shall be installed IAW reference [12].
6. MNT Panel 3108 shall be installed IAW reference [12].

9.5 Installation of Strain Gauges on Outer Skin

1. SGA The following strain gauges, as defined in Table 2, shall be prepared for installation:
 - a. CRPSS_505RL01
 - b. CRPSS_505RR01
 - c. CRPSS_514RL01
2. SGA For each of these locations the surfaces shall be prepared and strain gauges bonded IAW:
 - a. references [13 to 15],
 - b. the references specified in Table 2, and
 - c. Steps 4, 5, 6, 7, 8, 9, 10 and 12. of Section 9.3.

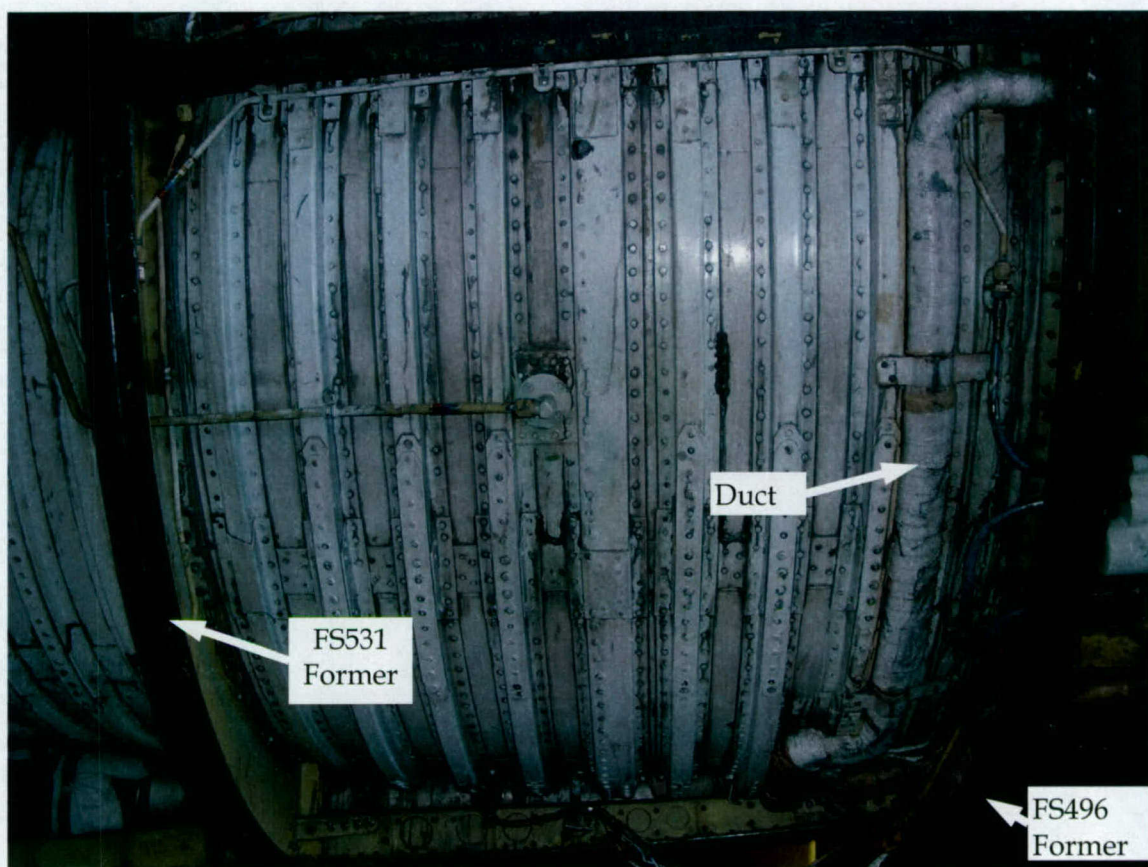


Figure 1: Photograph of installation location for Panel I.

10. Test Preparation

1. MNT Preparation for the CPLT shall be conducted IAW BASC standard operating procedures, with the addition of Steps 2 to 9 of Section 10.
2. DAS The data for the CRPSS shall be acquired using the DAS256 data acquisition system. This system shall condition and acquire the strain gauge outputs, and acquire loads from the CPLT load cell bridge A signal output. With the exception of the consolidated CPLT load signal (load line) acquired from the CPLT control cabinet, the DAS256 shall be operated completely independently of the CPLT control system and does not draw any electrical load, nor generate any signal, that may adversely affect the CPLT control system.
3. DAS If practicable, the calibration files for each of the load cells used in the CPLT shall be downloaded into the DAS256 prior to the CRPSS. This will facilitate validation of the CPLT loads data and reduce the post-processing required on the CRPSS data.
4. DAS The existing bulkhead blank-off panel in the CPLT chamber shall be removed and replaced with a blank-off panel that contains a hole (maximum diameter 50

mm) of sufficient diameter to egress all strain gauge lead-wires from the CPLT chamber to the CPLT control room. BASC shall provide the modified bulkhead blank-off panel.

5. DAS After the aircraft is safely in position within the CPLT chamber, the strain gauge and lead-wires shall be egressed from the aircraft, routed through the modified bulkhead blank-off panel and into the CPLT control room or wherever the DAS256 data acquisition system shall be located for the CRPSS. The shortest practicable path for the cable routing shall be used. The lead-wires shall be attached to the aircraft structure as required to support the loom without affecting the structural integrity of the aircraft. The attachment of lead-wires shall be performed using panduit tie straps or lacing cord.
6. DAS Each CPLT load cell contains three output leads corresponding to three independent Wheatstone bridge circuits. One of these circuits (bridge B) is connected to the CPLT control system and one (bridge C) is connected to the CPLT primary load measurement system (for slave load and reaction points). The third output (bridge A) is either vacant or sometimes connected to a backup load measurement system. This third load output lead (bridge A) on every load cell shall be connected to the DAS256 data acquisition system. The connection shall be made using a connector that matches the existing connector on the load cell output lead (8-pin AMP CPC Series 2 connector). The existing load cell output leads shall not be damaged or modified in any way. The load cell lead-wires shall be routed through the modified bulkhead blank off panel and into the underfloor space of the CPLT control room (requiring the removal of one floor panel) or wherever the DAS256 data acquisition system shall be located for the CRPSS. The shortest practicable path for the cable routing shall be used.
7. DAS The modified bulkhead blank-off panel shall be sealed using a cable gland and spray-on foam sealant.
8. DAS One of the signals generated by the CPLT control system is a consolidated load signal. Here the load cell signals are collapsed into a single 0-10 V signal that corresponds to 0-100% CPLT load. This signal may be accessed via a connector on the rear of one of the CPLT control panel. It shall be connected to the DAS256 data acquisition system. The connection shall be made using a connector that matches the existing connector (BNC connector). The existing CPLT load output connector shall not be damaged or modified in any way.
9. DAS All transducer lead-wires shall be connected to the external data acquisition system IAW reference [7].
10. DAS Performance checks shall be made IAW reference [7] to ensure that all strain gauge and load channels are functioning as desired. Troubleshooting shall be performed until all channels are functioning as desired.

11. CPLT

1. DAS The full Data Acquisition System shall be validated during a 20 % load run that shall be conducted prior to the CPLT.
2. DAS A reference sample shall be generated by sampling all channels immediately prior to the commencement of cooling (aircraft to be at ambient temperature under zero applied load). The data acquisition system shall be configured and operated in such a way that the readings called for in Step 3 of Section 11 can be made relative to this reference sample. This shall be used to establish the effect of cooling the aircraft to CPLT temperature (thermal effects).
2. CPL The aircraft shall be cooled to CPLT temperature (-40 °C) IAW BASC standard operating procedures.
3. DAS All data channels shall be sampled when the aircraft has stabilised at -40 °C but at zero applied load. This shall be combined with the data acquired in Step 1 of Section 11 to establish the thermal effects of cooling the aircraft.
4. CPL The CPLT loading shall be conducted IAW BASC standard operating procedures.
5. DAS All data channels shall be sampled during the application of each CPLT loadcase. The DAS operator shall record any noteworthy observations made during the CPLT, particularly deviations from normal.

12. Aircraft De-Modification

1. CPL Post-CPLT activities shall be conducted IAW BASC standard operating procedures.
2. DAS Upon return of the aircraft to ambient temperature and opening of the CPLT chamber, all lead-wires shall be disconnected from the data acquisition system.
3. DAS The strain gauge lead-wires shall be cut as close as practical to the strain gauge termination pad. Remove all panduit tie straps, stick on bases, adele clamps and lacing chord. Remove wires from the aircraft.
4. SGA The strain gauge lead-wires shall be disconnected from the data acquisition system and removed from the CPLT facility. The lead-wires may need to be cut out of the modified bulkhead blank-off panel. The lead-wires shall be disposed of in accordance with BASC disposal procedures.
5. DAS The modified bulkhead blank-off panel shall be removed and the original blank-off panel returned to position.
6. MNT With the aircraft in a convenient location (as decided by BASC), Panel I and Panel 3108 shall be removed from the aircraft IAW reference [12].

7. MNT Panel I shall be returned to the DSTO Task Manager.
8. MNT All strain gauges, except those bonded to Panel I, shall be removed from the aircraft IAW reference [18]. Note that if the chemical removal method is to be used then any sealant must be removed beforehand using a straight edges razor blade or scalpel.
9. MNT Repainting of all surfaces is to be conducted IAW reference [19]. Repaint the surface to restore the surface to its original state.
10. MNT Close out the unserviceabilities entered in the aircraft paperwork from Section 9.3.5.
11. MNT The aircraft shall be considered to have been returned to its original configuration. BASC shall conduct a PCA.

13. Data Analysis

1. DAS The data files shall be transferred to CD in an accessible format (MS Excel) then forward to the DSTO Task Manager for further analysis. The data shall be sufficiently well annotated, or accompanying notes shall be sufficiently detailed, so that the conditions under which the applicable section of data was acquired is clearly established.
2. SGA All data regarding the installed strain gauges, including the completed Strain Gauge Installation Proformas, Engineering Data Sheets, and installation photographs shall be forwarded to the DSTO Task Manager.

14. Safety

14.1 General

All activities associated with the CRPSS shall be conducted in accordance with:

- a. Occupational Health and Safety (Commonwealth Employment) Act 1991 (Commonwealth Requirements),
- b. Workplace Health and Safety Act 1995 (State Requirements),
- c. RAAF Publication DI(AF) PERS-60, and
- d. BASC safety requirements.

14.2 Specific to CRPSS

The hazards identified, and mitigation procedures, for the CRPSS are:

- a. Falls

The strain gauge locations on the upper longeron are above ground level.

There is a risk that personnel installing strain gauges may fall.

Strain gauges shall be installed from platforms adjusted to suit the height of the job.

b. Confined spaces

Some of the strain gauge lead-wires may need to be routed through confined spaces within the aircraft.

Installation in confined spaces shall be conducted IAW standard BASC operating procedures for confined spaces

c. Handling and storing of solvents and hazardous chemicals

There is a risk of inhaling, or absorbing through the skin, the solvents that used during cleaning and the chemicals used for strain gauge application.

The risk shall be mitigated by:

- (i) minimising the volume of solvent or chemical that is exposed to the environment by minimising the volume of solvent/chemical used and the time that containers are open to the atmosphere,
- (ii) ensuring adequate ventilation to dilute and dissipate vapours,
- (iii) the user of the solvents wearing appropriate personal protective equipment (PPE) including impervious gloves, impervious outer layer of clothing, appropriate breathing filter and safety glasses,
- (iv) all personnel that may breathe the vapours wearing appropriate breathing filters.

d. Machining composite materials

There is a risk of generating hazardous vapours and dust during the drilling and machining of the composite materials in Panel I.

The risk shall be mitigated by:

- (i) conducting all activities involved with composite materials IAW reference [17],
- (ii) performing all machining operations using tools that are designed for composite materials,
- (iii) wear appropriate PPE including a dust mask with an appropriate filter and safety glasses,
- (iv) extracting vapours and dust from their point of origin using a vacuum system. The vacuum nozzle should be as close as possible to the point of origin, preferably it should be built into the machining tool. The vacuum system shall pass all extracted air through a high quality filter designed for composite materials.
- (v) vacuum all work areas after machining operations have been completed. Use a vacuum system that passes all extracted air through a high quality filter designed for composite materials.

15. References

1. Harman, A. B. and Callus, P. J., *Structural Analyses of a Demonstrator Composite Replacement Panel in a F-111C Cold Proof Load Test*, Defence Science and Technology Organisation, DSTO-TN-0546, March 2004, 89 pp.
2. Cooper, T., *F-111 Composite Replacement Panel Strain Survey, Phase II - Engineering Review*, ER-F111-51-ASM337, AeroStructures, 14 April 2004

3. Harper, A., *Statement of Work for F-111C Composite Replacement Panel Strain Survey*, AeroStructures, Spec-F111-80081, SOW2 4-13-24-2-Issue1, 21 May 2004, 19 pp.
4. Harper, A., *Statement of Requirement for F-111C Composite Replacement Panel Strain Survey*, AeroStructures, SOR2 4-13-24-2-Issue1, 21 May 2004, 28 pp.
5. Harper, A., *Design Development Plan for F-111C Composite Replacement Panel Strain Survey*, AeroStructures, DDP2 4-13-24-2-Issue1, 21 May 2004, 12 pp.
6. General Dynamics, *Test Loads and General Test Procedures for the F-111 Proof Test Program ECP 2739R03 & R04*, FZS-12-308B, 17 June 1970.
7. Parkhill, G. J., *DAS256 Data Acquisition System, System description, calibration and data file format*, filename: das_256description.doc, PraxSys Pty. Ltd., 18 December 2003, 8 pp.
8. Fitzgerald, M., *Paint removal from D6ac steel for strain gauge installation*, Work Instruction WI-005, Commercial-in-Confidence, Fortburn Pty Ltd, May 2003, 1 pp.
9. Fitzgerald, M., *Strain gauge installation using M-Bond 200 adhesive on D6ac*, Work Instruction WI-037, Commercial-in-Confidence, Fortburn Pty Ltd, June 2003, 4 pp.
10. Fitzgerald, M., *Paint removal from aluminium surfaces for strain gauging*, Work Instruction WI-042, Commercial-in-Confidence, Fortburn Pty Ltd, May 2004, 1 pp.
11. Fitzgerald, M., *Strain gauge installation using M-Bond 200 adhesive*, Work Instruction WI-022, Commercial-in-Confidence, Fortburn Pty Ltd, June 2003, 4 pp.
12. Royal Australian Air Force, DI(AF) AAP 7214.003-2-2-1, Section VII, Maintenance Fuselage and Empennage.
13. Royal Australian Air Force, DI(AF) AAP 7214.003-3, Section 12, Repair and Overhaul Instructions F-111C Aircraft.
14. Royal Australian Air Force, DI(AF) AAP 7214.003-2-13-1, Electrical Power and Lighting Systems F/RF-111C Series Aircraft.
15. Royal Australian Air Force, DI(AF) AAP 7021.004-1, Aircraft Finishing Schemes Internal External.
16. Fortburn Pty Ltd, *Fortburn strain gauge installation sheet*, FQC043, Fortburn Pty Ltd, 1pp.
17. Bitton, D., *Trim and drill procedures for the installation of a composite replacement panel*, CRC-ACS-PS-511B-001, Commercial-in-confidence, Cooperative Research Centre for Advanced Composite Structures, June 2002, 13 pp.
18. Fitzgerald, M., *Strain gauge removal M-Bond 200*, Work Instruction WI-029, Commercial-in-Confidence, Fortburn Pty Ltd, May 2003, 1 pp.
19. Royal Australian Air Force, *Corrosion Control and Marking Manual F-111C Aircraft*, DI(AF) AAP 7214.003-23.

Appendix A: Strain Gauge Details

Axial strain gauges were selected for the sub-structure because the major loading in these components was predicted to be parallel to the longitudinal axis of these structures. 0/45/90 rosettes were selected for the panels because significant in-plane shear was predicted to occur in these structures. Stacked rosettes were selected for use in some cases because there was limited room to apply rosettes that had the legs lying adjacent to each-other.

Five different types of strain gauges, as detailed in Table A.1, have been selected. The strain gauge dimensions are defined in Fig. A1 and the layout of the detailed gauges shown in Fig. A.2. Although the Micro-Measurements strain gauge designations are given, the strain gauge contractor is permitted to substitute any of these strain gauges with gauges of their choice, provided that the substitutes have the same:

- | | | |
|----|----------------------------------|--|
| a. | type of grid | axial, side-by-side rosette or stacked rosette |
| b. | grid length | 1.57 mm or 6.35 mm |
| c. | coefficient of thermal expansion | 00, 06 or 13 $\text{m m}^{-1} \text{ }^{\circ}\text{C}^{-1}$ |
| d. | resistance | 350 Ω |

Table A.1. Strain gauge details

Micro-Measurements strain gauge designation	Location	Grid (mm)		Overall (mm)		Matrix (mm)	
		Length	Width	Length	Width	Length	Width
CEA-06-062UW-350	FS496 Former & Lower beam	1.57	3.05	5.59	3.05	7.9	4.8
CEA-13-250UN-350	FS531 Former	6.35	3.05	10.54	3.05	13.2	5.6
CEA-06-250UR-350	Lower skin	6.35 ¹	3.05 ¹	12.70 ²	19.30 ²	16.5	20.3
CEA-13-250UW-350	Upper longeron	6.35	4.57	11.43	4.57	14.0	6.9
CEA-13-250UR-350	Panel 3108	6.35 ¹	3.05 ¹	12.70 ²	19.30 ²	16.5	20.3
SA-00-250WR-350	Panel I	6.35 ¹	3.18 ¹	-	-	13.0	15.2

Notes

- ¹ Each grid section
- ² Complete package including all grids

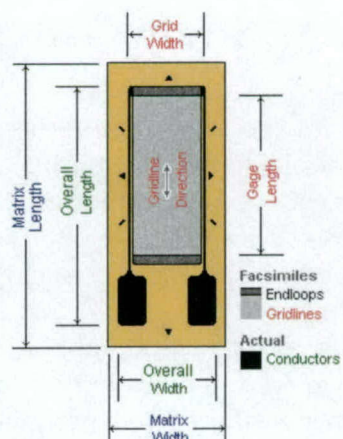


Figure A.1: Reference for strain gauge dimensions

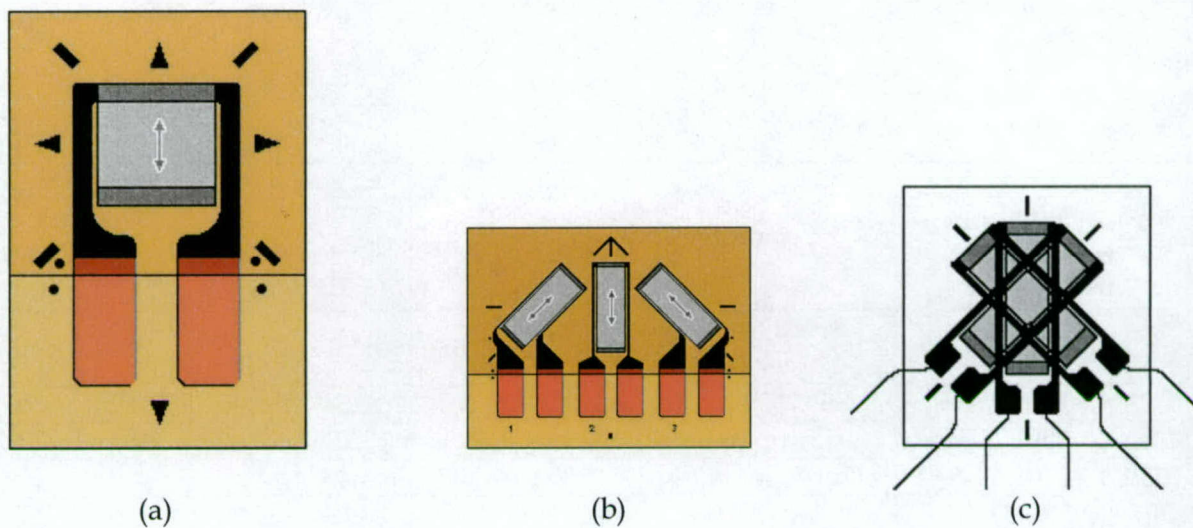


Figure A.2: Layout of (i) UW and UN, (ii) UR and (iii) WR type strain gauges

Appendix B: Strain Gauge Locations

The strain gauge positions for the CRPSS are shown in Figures B.1 to B. 8.

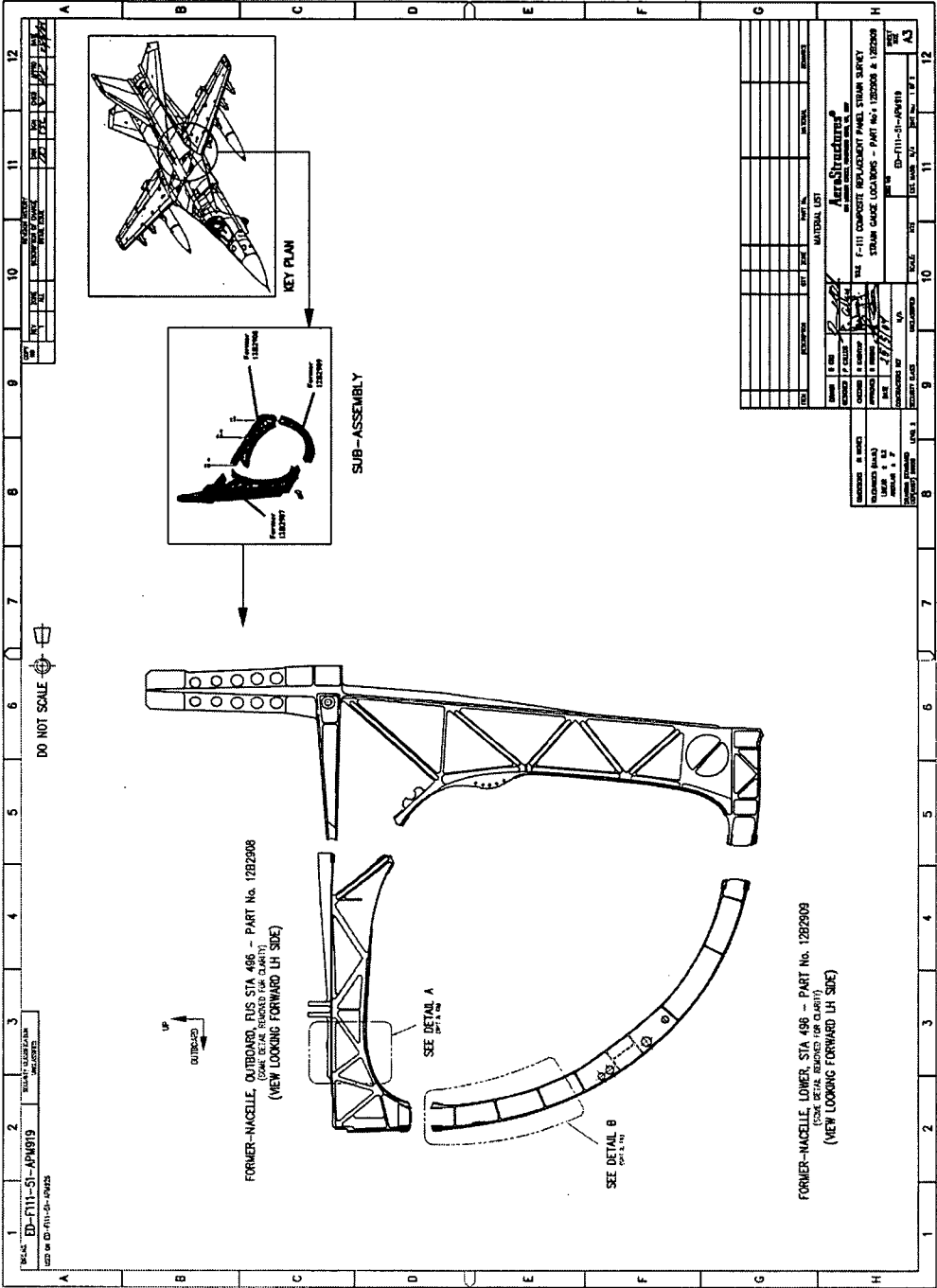
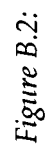


Figure B.1: AeroStructures Drawing ED-F111-51-APM919 Sheet 1 showing the general position of strain gauges on the FS496 Former (Part Numbers 12B-2908 and 12B-2909)



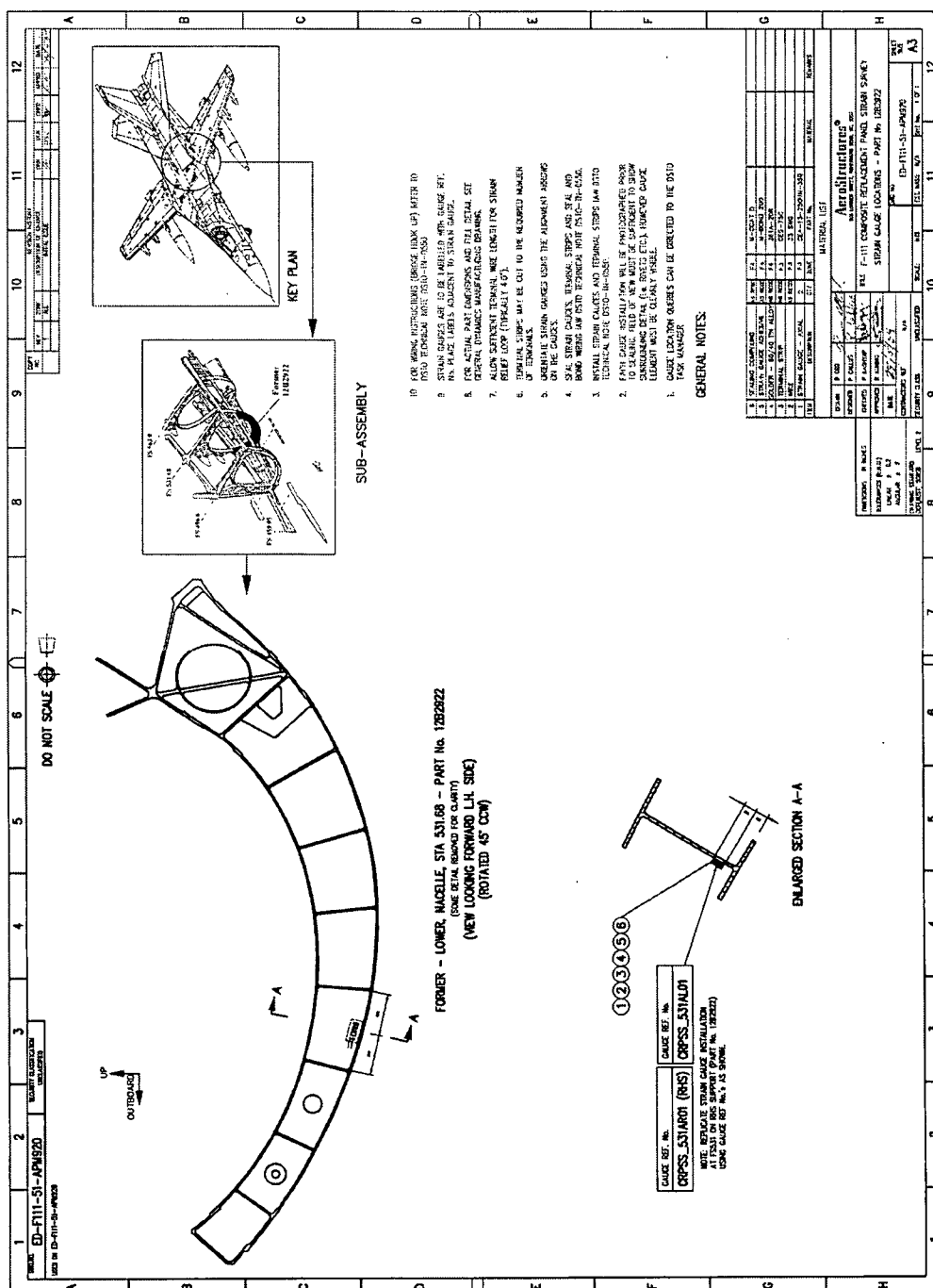


Figure B.3: AeroStructures Drawing ED-F111-51-APM920 showing position of strain gauges on the FS531 Former (Part Number 12B-2922.)

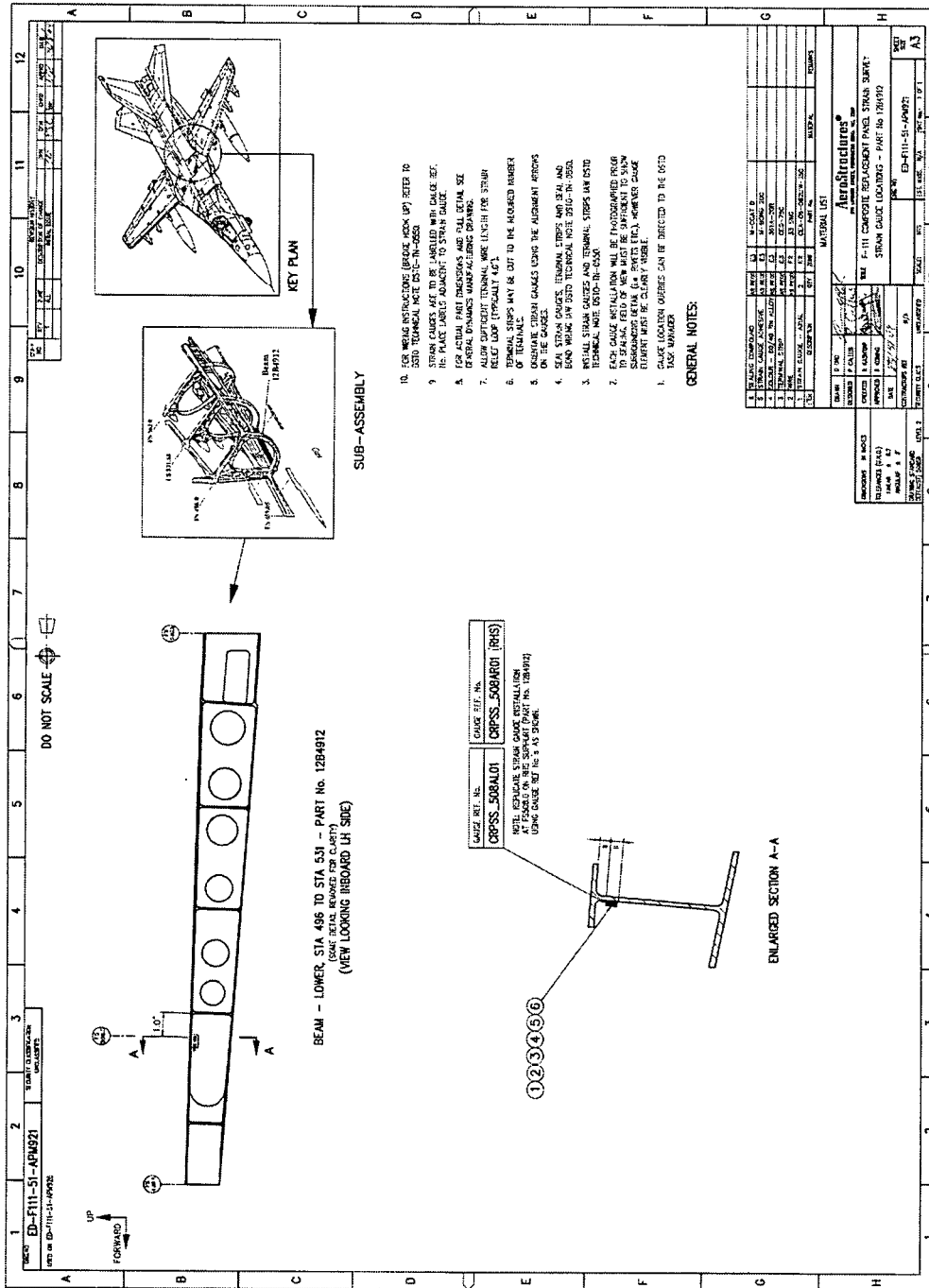


Figure B.4: AeroStructures Drawing ED-F111-51-APM921 showing the general position of strain gauges on the Lower Beam (Part Number 12B-4912)

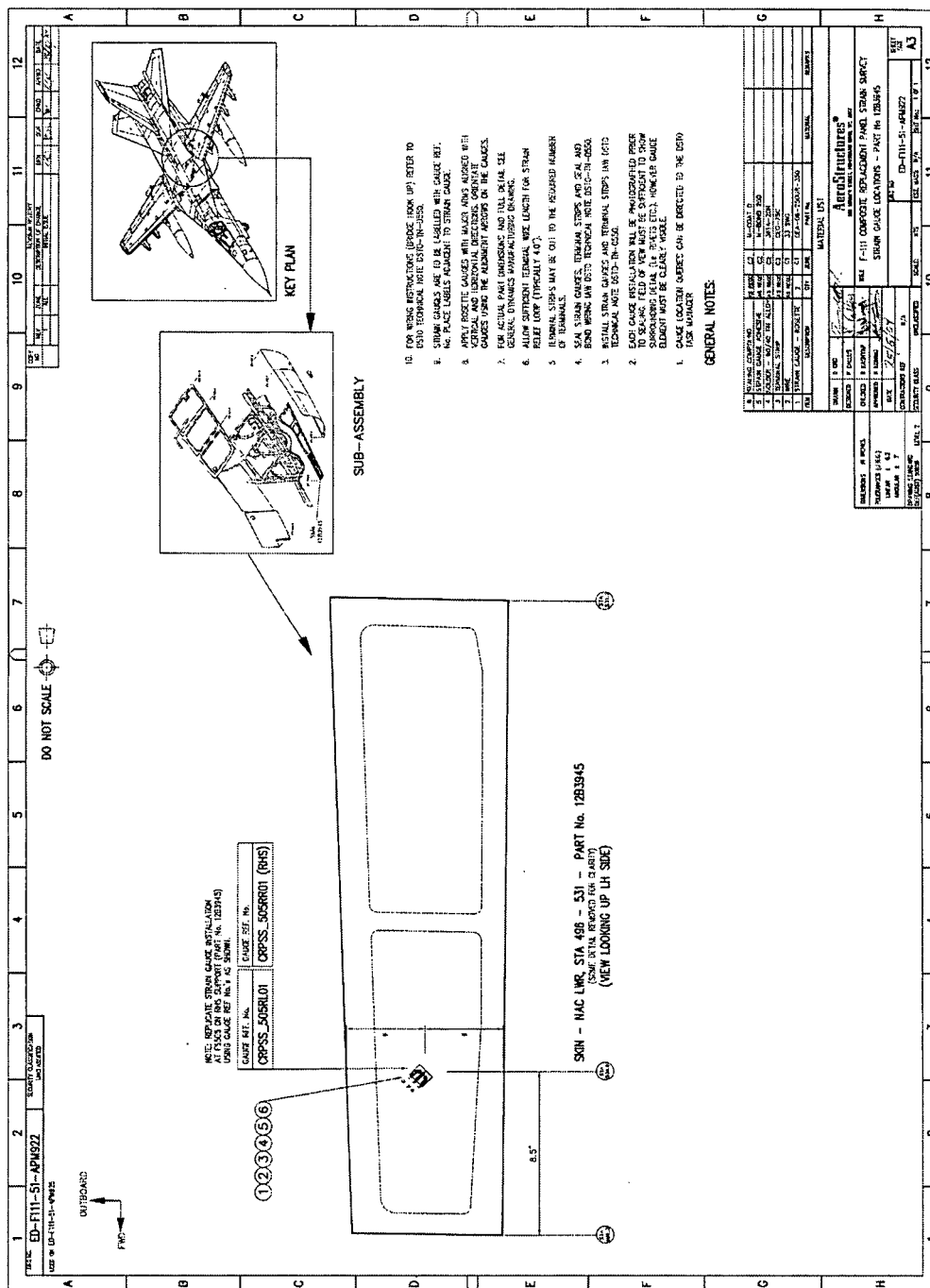
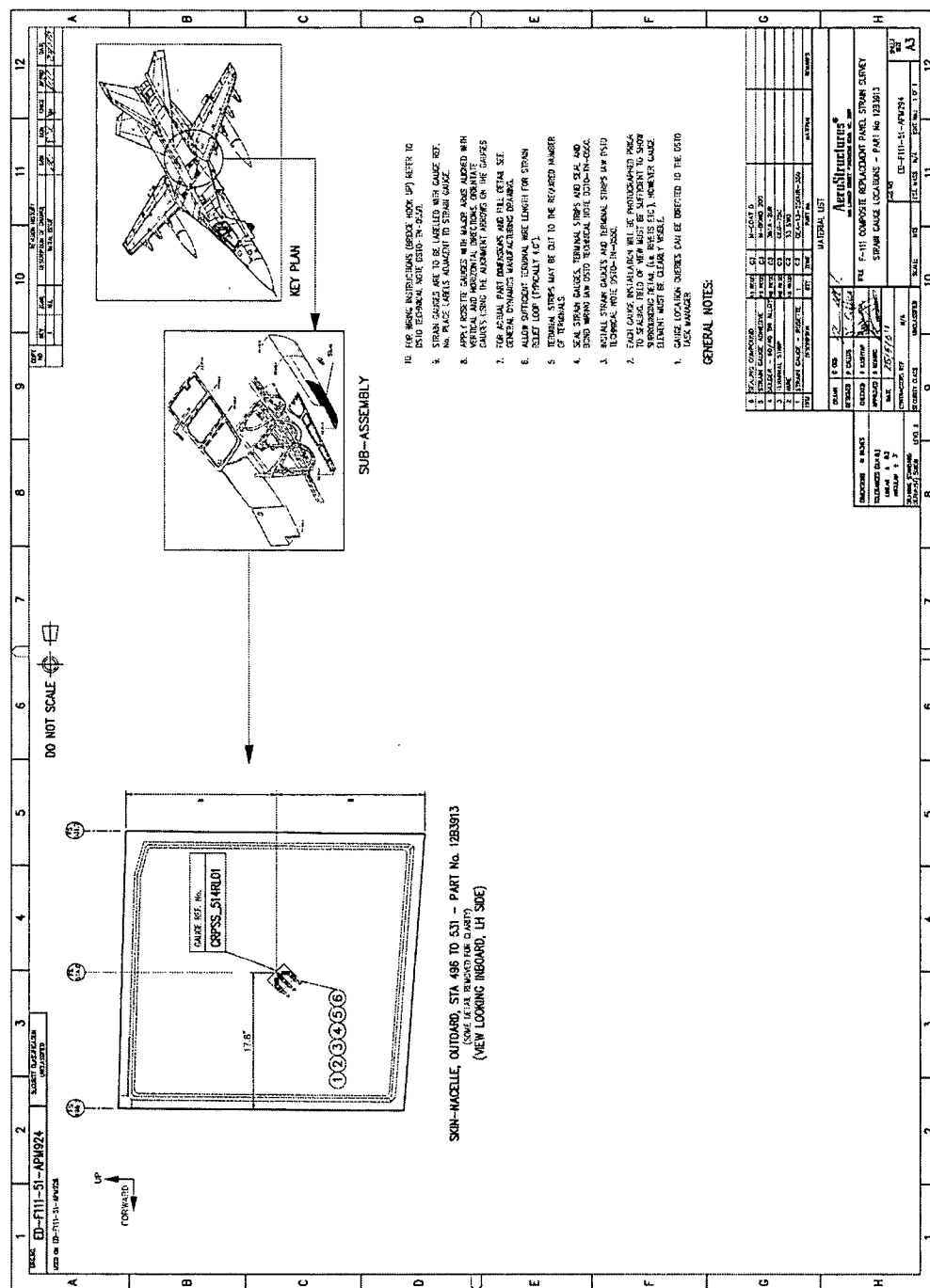




Figure B.6: AeroStructures Drawing ED-F111-51-APM923 showing the general position of strain gauges on the Longeron (Part Number 12B-1904)





Appendix C: Stiffener Reinforcement

1. This procedure shall be conducted IAW BASC OH&S procedures.
2. Trim hats and webs until there is sufficient clearance between the top of the webs and the duct in the presence of the reinforcement (as an initial estimate, trim to give an approximately 3 mm clearance from the duct). Clean edges with 220 grit wet/dry paper.
3. Shape a piece of 0.5 mm thick aluminium sheet to act as a bed for the reinforcement as shown in Fig. C.1. The bed shall be flat and flush with the edge of the trimmed webs to a tolerance of ± 1 mm).
4. Cover aluminium bed with flashbreak tape (release media).
5. Produce a paper template for the reinforcement plies. The size of the template shall be sufficient to supply the plies as shown in Fig. C.2
6. Using the template as a guide, cut three $\pm 45^\circ$ plies of 200 gsm carbon plain weave fabric (SP Systems RC 200P (195 gsm HS-3k fibre) or equivalent).

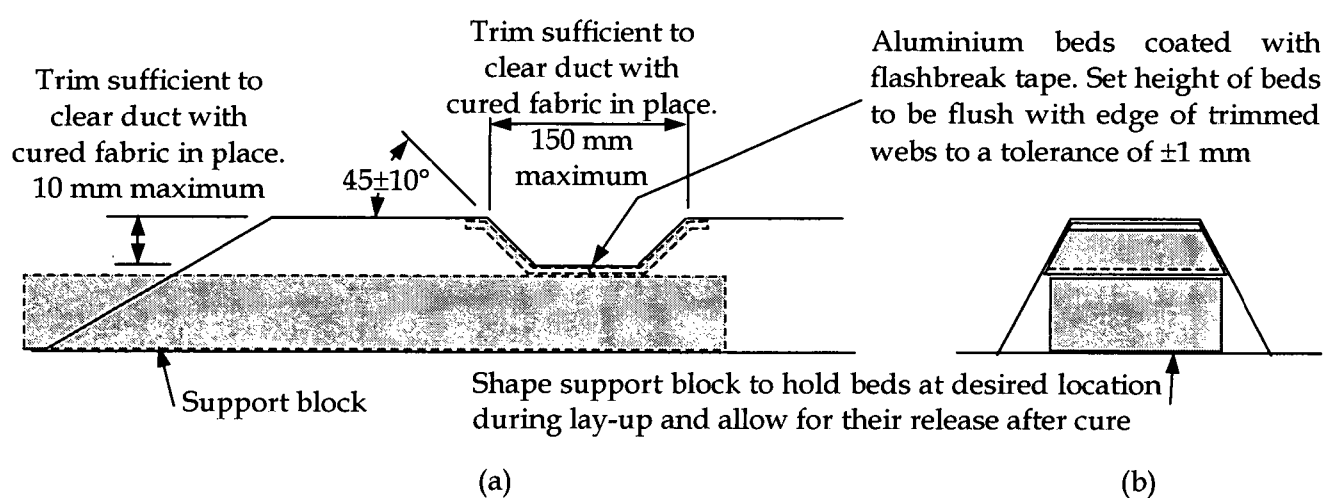


Figure C.1: Diagram of (a) cross-section, and (b) end view, of a trimmed hat stiffener showing the important dimensions and the shaped aluminium beds.

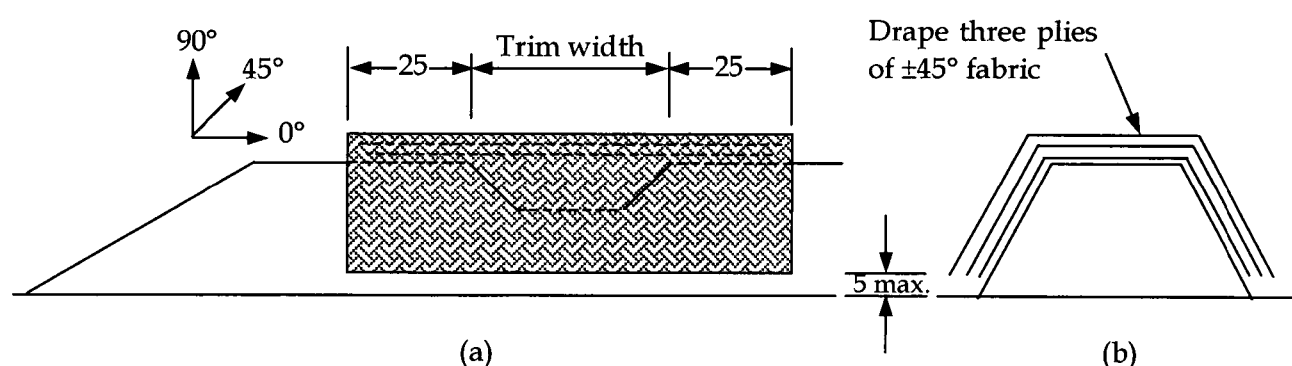


Figure C.2: Diagram of (a) cross-section, and (b) end view, of a trimmed hat stiffener showing the dimensions and orientation of the fabric reinforcement. All dimensions in mm.

7. The following surface preparation shall be conducted:
 - a. Mask the periphery of the area to be reinforced with masking tape. The exposed area shall match the size of the reinforcement plies.
 - b. Lightly abrade the surface of the hat stiffener to be bonded with 320 grit abrasive paper. Abrade just enough to remove the surface resin and expose fresh resin over the entire area. Take care to minimise the damage to any fibres by not over-abrading.
 - c. Remove debris from the clean surface by blowing with compressed dry nitrogen.
8. Locate and immobilise the aluminium beds in the position shown in Fig. C. 1.
9. Warm the surface to be reinforced to 30 °C using available equipment (heating lamp with temperature controller).
10. After warming has commenced, mix sufficient quantity of Hysol EA9396 (BMS-301 Class 3) laminating resin to perform the reinforcement.
11. Wet the surface of the masked area using the laminating resin and a clean brush. Place the first ply on the wet resin and work the fabric down onto the insert with finger pressure and by stippling the fabric with the resin coated brush. Continue pressing/stippling until the fabric attains, and retains, the profile shown in Fig. C.3 and is fully wetted out by the resin. Maintaining the ply orientation at strictly $\pm 45^\circ$ is less important than ensuring the fabric remains against the aluminium bed. The plies may be cut to drape smoothly over the webs.
12. Locate second ply over the first ply and stipple with a brush to conform the second ply to shape of the first and to wet out the second ply. Add resin as required to ensure the ply is fully wetted out.
13. Repeat step 12 using the third reinforcement ply.
14. Wipe excess resin off the masking tape.
15. Allow the resin to gel (B-stage). Remove the masking tape within one minute of gellation. The resin will be soft enough to remove the tape easily but firm enough to retain the straight edge.
16. Allow the resin to cure for eight hours at a temperature of 40 °C (under the heat lamp).
17. Remove the aluminium beds, taking care not to damage any of the existing structure during removal.
18. Trim the edges of the reinforcement area using 220 grit wet/dry paper and clean with isopropyl alcohol.

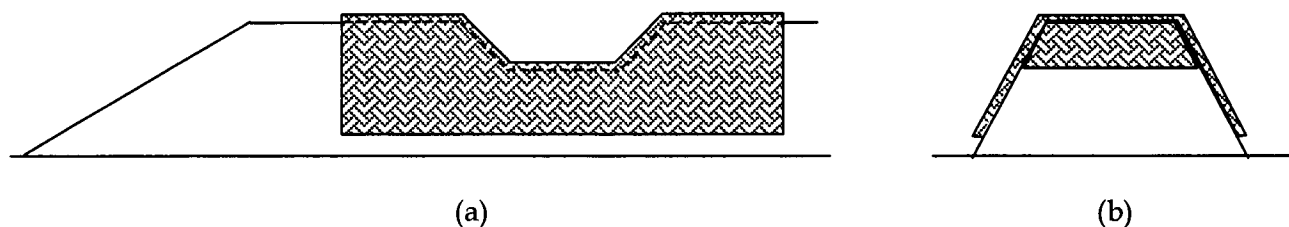


Figure C.3: Diagram of (a) cross-section, and (b) end view, of the cured reinforcement.

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Paul J. Callus and Anthony Harper

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19. ABSTRACT The Defence Science and Technology Organisation, in collaboration with the Cooperative Research Centre for Advanced Composite Materials, is developing the capability to replace metallic aircraft panels with those manufactured from advanced fibre composites. This is known as the Composite Replacement Panel Technology (CRPT). One step toward airworthiness certification of the CRPT is a validated capability to predict strain within a composite replacement panel (CRP) and the aircraft sub-structure. The strain data required for this validation shall be obtained in the Composite Replacement Panel Strain Survey (CRPSS). In the CRPSS, the strains within a demonstrator CRP installed on a F-111C aircraft shall be measured during a Cold Proof Load Test to be conducted at RAAF Base Amberley in June 2004. This report describes the procedures to be used for the CRPSS.					